



RESEARCH DEPARTMENT

REPORT

---

# **An Extended PAL system for high-quality television**

A. Oliphant, M.A., C.Eng., M.I.E.E.



## AN EXTENDED PAL SYSTEM FOR HIGH-QUALITY TELEVISION

A. Oliphant, M.A., C.Eng., M.I.E.E.

### SUMMARY

*An Extended PAL system is described which virtually eliminates cross-colour and gives improved luminance resolution for high quality receivers while retaining compatibility with conventional PAL decoders. The system uses the extra bandwidth available in a satellite or cable transmission channel to transmit the high frequency part of the luminance signal outside the normal video band.*

*Tests are described which have shown that the wider-bandwidth Extended PAL signal can be passed through a 27 MHz f.m. channel as foreseen for direct broadcasting from satellites, without causing noticeable distortions. Subject to the availability of high definition displays, it would give domestic viewers considerable improvement in picture quality with an acceptable small penalty in signal-to-noise ratio.*

Issued under the authority of

Research Department, Engineering Division,  
BRITISH BROADCASTING CORPORATION

December 1981  
(PH-242)



Head of Research Department



# AN EXTENDED PAL SYSTEM FOR HIGH-QUALITY TELEVISION

| Section   | Title                                     | Page              |
|-----------|---|-------------------|
|           | <b>Summary</b> .....                      | <b>Title Page</b> |
| <b>1.</b> | <b>Introduction</b> .....                 | <b>1</b>          |
| <b>2.</b> | <b>The Extended PAL system</b> .....      | <b>1</b>          |
|           | 2.1. General considerations .....         | 1                 |
|           | 2.2. Description of the system .....      | 2                 |
|           | 2.3. An Extended PAL coder .....          | 2                 |
|           | 2.4. Extended PAL decoder .....           | 3                 |
| <b>3.</b> | <b>Preliminary results</b> .....          | <b>4</b>          |
|           | 3.1. Experimental coder and decoder ..... | 4                 |
|           | 3.2. Picture quality .....                | 5                 |
|           | 3.3. Tests with f.m. modem .....          | 7                 |
| <b>4.</b> | <b>Conclusions</b> .....                  | <b>9</b>          |
| <b>5.</b> | <b>References</b> .....                   | <b>9</b>          |

© BBC 2006. All rights reserved. Except as provided below, no part of this document may be reproduced in any material form (including photocopying or storing it in any medium by electronic means) without the prior written permission of BBC Research & Development except in accordance with the provisions of the (UK) Copyright, Designs and Patents Act 1988.

The BBC grants permission to individuals and organisations to make copies of the entire document (including this copyright notice) for their own internal use. No copies of this document may be published, distributed or made available to third parties whether by paper, electronic or other means without the BBC's prior written permission. Where necessary, third parties should be directed to the relevant page on BBC's website at <http://www.bbc.co.uk/rd/pubs/> for a copy of this document.

# AN EXTENDED PAL SYSTEM FOR HIGH-QUALITY TELEVISION

## A. Oliphant, M.A., C.Eng., M.I.E.E.

### 1. INTRODUCTION

Present-day composite television systems - NTSC, PAL and SECAM - are well-matched to present-day transmission channels and display devices. Picture quality is limited both by the bandwidth of the transmission channel - chosen for compatibility with monochrome signals - and by the resolution of picture tubes in domestic receivers. In addition, the need for compatibility with existing monochrome signals, which was essential when colour services began, imposes the composite shared-band colour systems with their associated impairments of crosscolour and crossluminance\*, which also limit picture quality. The elimination of these crosseffects will be particularly desirable if higher-definition larger-screen displays become available in domestic receivers.

Previous work on the reduction of PAL crosseffects has concentrated on compatibility with existing PAL transmissions within the 5.5 MHz bandwidth allowed by terrestrial broadcast channels. Two proposals [1, 2] have been published for improved methods of PAL coding and decoding. These methods use various forms of comb filter based on line delays to reduce or eliminate PAL crosseffects at the expense of introducing less objectionable impairments such as the reduction of vertical chrominance resolution and diagonal luminance resolution or the introduction of a luminance alias component. They have the advantage that they are completely compatible with existing PAL coders and decoders; but they have not so far been judged to produce sufficient improvement to justify their introduction. However, it is likely that there will be further developments using these principles, possibly using field delays or picture delays; the cost of storage is falling so fast that it should soon be possible to include this amount of storage in a high-quality domestic receiver.

A different approach to the reduction of PAL crosseffects will become possible if wider bandwidth channels become available from satellites or wide-band cable systems. This Report describes an Extended PAL system in which a wider bandwidth

is used to transmit chrominance and luminance signals in separate frequency bands, while retaining complete compatibility with existing PAL decoders.

### 2. THE EXTENDED PAL SYSTEM

#### 2.1. General considerations

Two points need to be considered in the design of an improved television transmission system. One is compatibility with existing receivers; the other is matching the signal to the characteristics of the transmission channel. It is likely that transmission restrictions will be more stringent in a satellite channel rather than a cable system.

Present-day receivers restrict the luminance bandwidth by a roll-off in the tuner and i.f. circuitry and by the notch filter used in the PAL decoder to remove plain-area subcarrier. Modern in-line picture tubes also restrict the luminance bandwidth that can be displayed; and any high-frequency luminance that is displayed is largely masked by the crosscolour that it causes. Thus the viewers of future services who continue to use the currently manufactured sets would lose little if luminance above about 3.5 MHz were removed from the baseband PAL signal and frequency-shifted outside the present video band. In fact, the viewer would gain, because crosscolour would be virtually eliminated. Previous work [3] has shown that a 3.5 MHz lowpass filter in the luminance circuit of a PAL coder is subjectively indistinguishable from the notch filter sometimes used to reduce crosscolour. In a high-quality receiver of the future the out-of-band high-frequency luminance could be shifted back and added to the baseband low-frequency luminance to give a high-definition picture free from crosscolour. Thus a PAL signal with high-frequency luminance shifted outside the present video band could give much improved picture quality in the future, while remaining compatible with present-day PAL decoders.

The planned satellite channels are 27 MHz wide and were intended to take a conventional composite video signal with associated sound signals, frequency modulated onto a carrier at about 12 GHz. The matching of an Extended PAL signal to such a channel is difficult to predict theoretically; the video and modulation parameters have to be balanced by experiment. The promising preliminary

\*Crosscolour is the spurious coloured pattern caused by high-frequency luminance detail being interpreted by the decoder as chrominance; crossluminance is the fine luminance pattern caused by residual colour subcarrier.

results (see Section 3.3) indicate that it should be possible to obtain a satisfactory balance.

## 2.2. Description of the system

The system can best be understood by considering signals in the frequency domain. Fig. 1a shows the luminance spectrum and Fig. 1b shows the present chrominance spectrum. For present terrestrial transmission both spectra extend only to 5.5 MHz, but in an extended system a wider bandwidth might be possible, depending on the channel characteristics. This possible extension is indicated in the Figure by ending the spectra in dotted lines. The luminance spectrum is split into low frequency ( $Y_1$ ) and high frequency ( $Y_2$ ) parts as shown in Fig. 1c. The high frequency part is frequency shifted by multiplying it by a suitable carrier frequency, shown in Fig. 1d, producing the spectrum shown in Fig. 1e. The unwanted components near the origin are removed by highpass filtering to leave the frequency shifted components  $Y_2$ . This process of frequency shifting may also be thought of as suppressed-carrier single-sideband modulation of the high frequency luminance signal onto the carrier frequency. A similar multiplication process in the receiver shifts the high frequency luminance back to its proper place so that it can be

added back to the low-frequency luminance. This is shown in Fig. 2.

In Fig. 1, the frequency shown for shifting the high-frequency luminance is the PAL subcarrier frequency  $f_{sc}$ . The advantages of using this frequency are:

- (i) it is available in both coder and decoder with accurately known phase.
- (ii) any carrier remaining in the demodulated signal has low visibility because the exact frequency of the colour subcarrier is chosen for minimum visibility.
- (iii) the use of only one carrier frequency precludes the possibility of intermodulation between two carriers producing low-frequency beat patterns.

## 2.3. An Extended PAL coder

In a conventional PAL coder, shown in Fig. 3, Red, Green and Blue signals are matrixed to luminance ( $Y$ ) and two colour difference signals ( $U$  and  $V$ ). The  $Y$  signal may be notch filtered to attenuate components near subcarrier frequency which would cause crosscolour; the  $U$  and  $V$  signals are lowpass filtered and modulated in quadrature

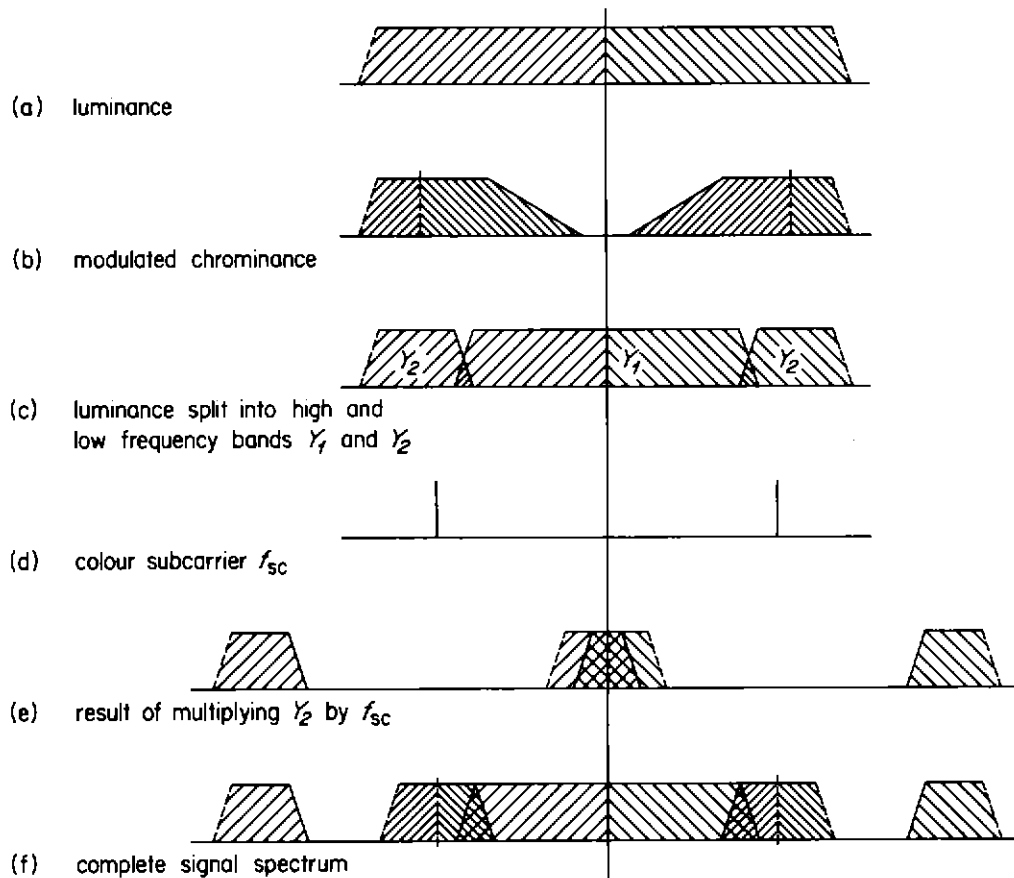


Fig. 1. Spectra in the coding process

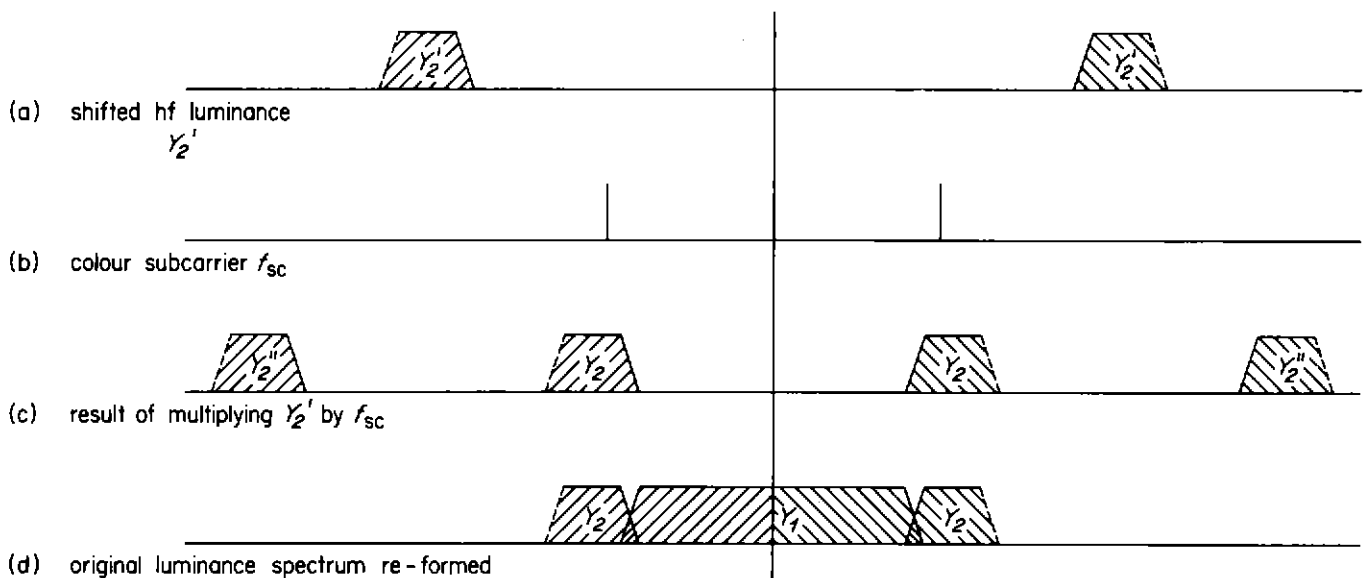
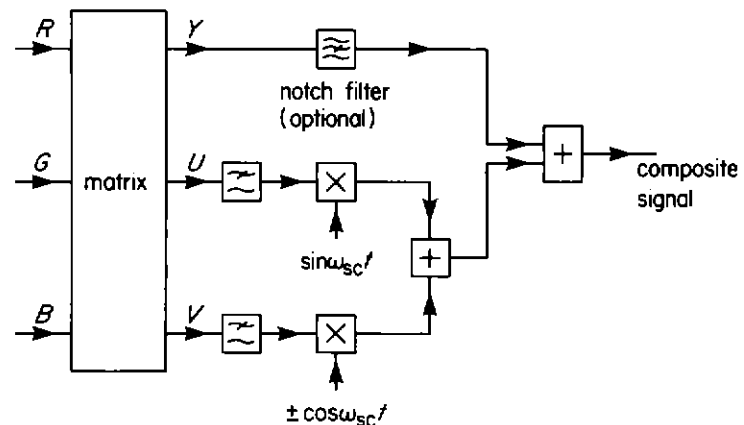


Fig. 2. Spectra in the decoding process

Fig. 3. Block diagram of a conventional PAL coder



onto the colour subcarrier frequency  $f_{sc}$ . The signals are then added together to produce the composite PAL signal. The  $U$  and  $V$  lowpass filters are approximately Gaussian, so the lower sideband of the modulated chrominance signal extends below 1 MHz, as shown in Fig. 1b. This improves monochrome compatibility, but causes worse cross-luminance (visible as a moving dot pattern on vertical chrominance edges) on a colour picture.

In the Extended PAL coder shown in Fig. 4 the chrominance modulation is exactly as in the conventional coder. A highpass filter may be used to attenuate the lower sideband of the modulated chrominance signal (below about 3.5 MHz) to reduce crossluminance in the decoded signal. The luminance signal is split into two bands,  $Y_1$  (below about 3.5 MHz) and  $Y_2$  (above about 3.5 MHz). The  $Y_2$  signal is frequency shifted by multiplying by a sinewave of colour subcarrier frequency followed by highpass filtering to remove unwanted components near zero frequency. The specification of

the highpass filter is not critical, but it is convenient for it to have a zero at colour subcarrier frequency to remove any subcarrier breakthrough from the modulation process. The band splitter may contain a highpass and a lowpass filter or it may use the complementary arrangement shown in Fig. 5. This has the advantage that the bandsplitting process is controlled by only one filter. If a highpass and a lowpass filter are used, then a slight frequency overlap may be permitted between the high-frequency and low-frequency luminance in the transmitted signal; the band split is then defined by a complementary filter in the decoder, as shown in Fig. 6.

#### 2.4. Extended PAL decoder

Two methods of decoding are possible with Extended PAL signals. If the signal is lowpass filtered it can be decoded by a conventional decoder as shown in Fig. 7. Plain-area subcarrier is removed from the luminance signal by a notch filter and the

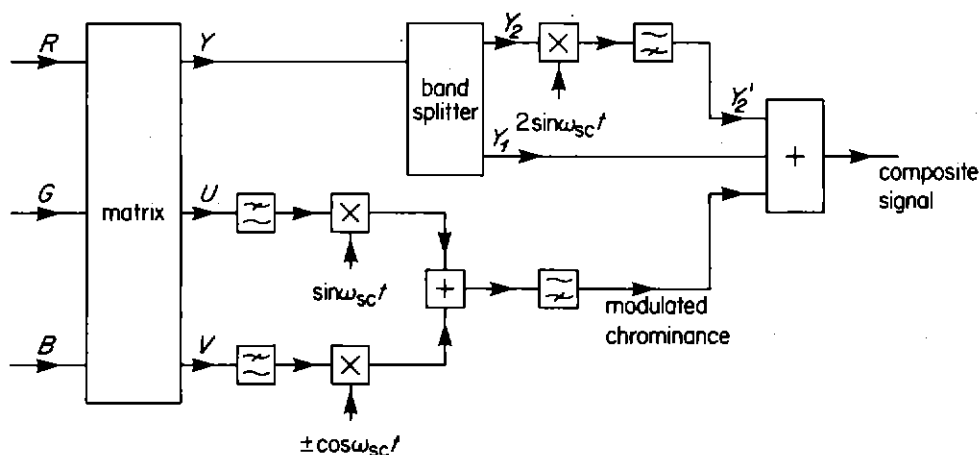


Fig. 4. Block diagram of a compatible Extended Pal coder

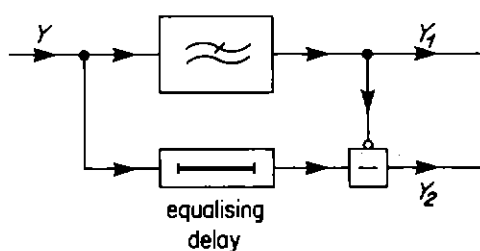


Fig. 5. Complementary band-splitting filter

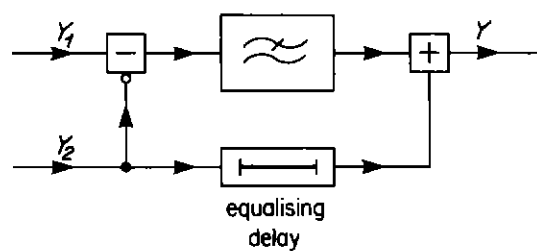
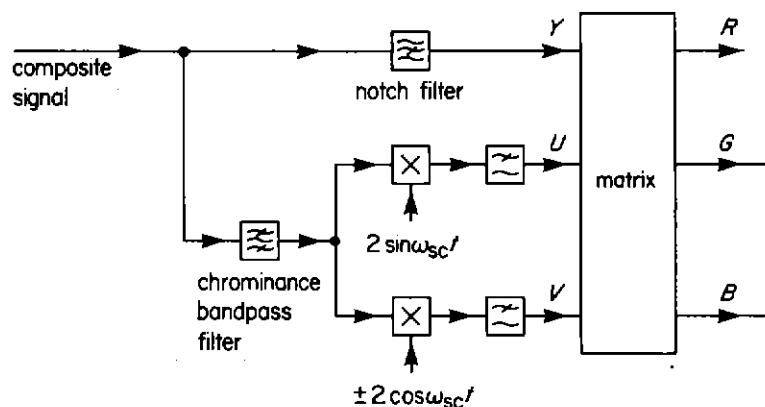


Fig. 6. Complementary combining filter for two frequency bands

Fig. 7. Block diagram of a conventional PAL decoder



chrominance is demodulated by multiplying by quadrature subcarriers and lowpass filtering. The chrominance bandpass filter shown is not strictly necessary, but is commonly used to reduce intermodulation products caused by nonlinearity in the multiplication process. The luminance and colour difference signals are matrixed back to Red, Green and Blue to drive the display tube.

However, the system can also be used with a high quality decoder as shown in Fig. 8. In this decoder the chrominance is demodulated in the conventional manner. The composite signal is low-pass filtered to give low-frequency luminance  $Y_1$  and highpass filtered to give shifted high-frequency luminance  $Y_2$ . This signal is shifted back to

baseband by multiplying it by a subcarrier-frequency sinewave and lowpass filtering to remove unwanted components near  $3f_{sc}$ . The two components  $Y_1$  and  $Y_2$  are added together to form a complete luminance signal which is fed to the output matrix.

### 3. PRELIMINARY RESULTS

#### 3.1. Experimental coder and decoder

An experimental coder and decoder have been built to investigate the properties of the Extended PAL system. The coder used a BBC-designed PAL coder with extra circuitry to carry out the splitting of the luminance signal and the

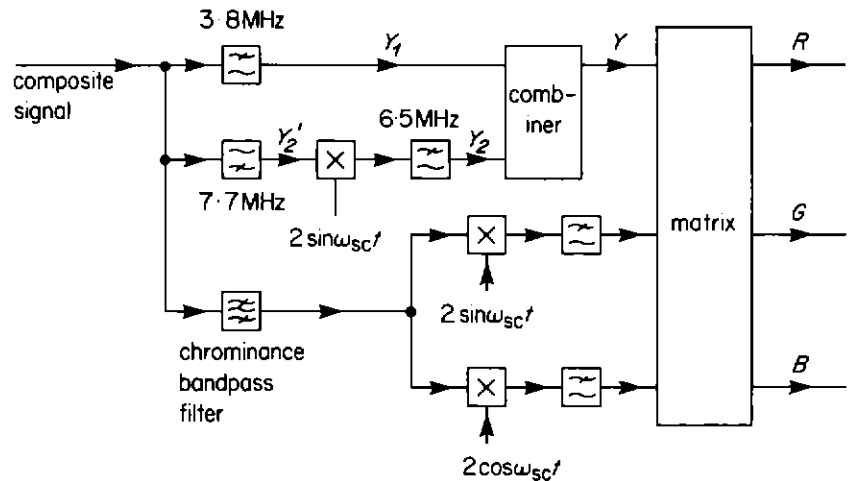


Fig. 8. Block diagram of a high-quality Extended PAL decoder

modulation of the high-frequency part; the decoder was built around a modified commercial PAL decoder.

A complementary band-splitting filter as shown in Fig. 5 was used in the coder. The amplitude-frequency characteristic of the lowpass filter is shown in Fig. 9. This characteristic was chosen to give a reasonable compromise between ringing and loss of resolution in the compatible picture on one hand, and reduction of crosscolour in both the compatible picture and the high-quality picture on the other. The decoder used highpass and lowpass filters to separate the two luminance signals  $Y_1$  and  $Y_2$  and a simple resistive adder to combine the demodulated high-frequency signal,  $Y_2$ , with  $Y_1$ .

### 3.2. Picture quality

The improvement in picture quality from the Extended PAL system can be seen in Fig. 10, 11 and 12. These pictures show BBC Test card F; they were taken from a monochrome monitor fed with the green signal from a decoder. Fig. 10 shows the

green signal from a conventional PAL decoder fed by a conventional coder. Crosscolour can be seen on the resolution gratings, on the diagonal bars at the corners of the picture and on all sharp horizontal transitions. The notch filter in the decoder has attenuated the 4.5 MHz resolution grating and has caused ringing following transitions.

Fig. 11 shows the green signal from a conventional decoder fed with the low frequency part of the Extended PAL signal – that is with the luminance above 3.5 MHz removed. The resolution gratings at 4.5 MHz and 5.25 MHz have been lost, and some ringing is visible; however, virtually all the crosscolour has also gone, and the ringing is similar to that from the notch filter in Fig. 10. Although the effect of lowpass filtering is obvious on a Test Card with its resolution gratings, the effect on real picture material is very small. It is noteworthy that the lowpass filtered signal is indistinguishable from the signal from a PAL coder with a crosscolour-reducing notch filter [3] in its luminance path.

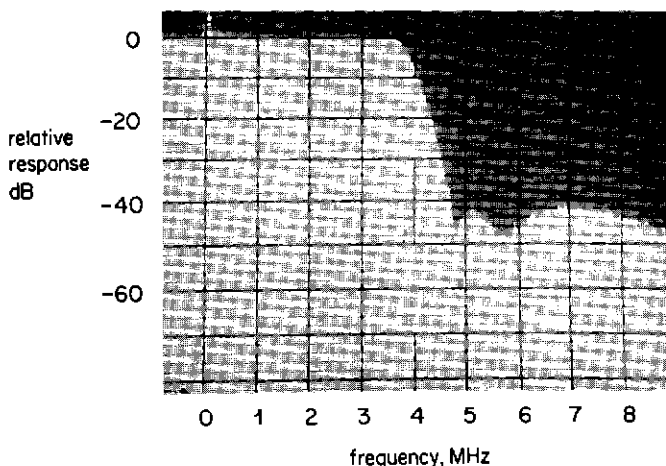
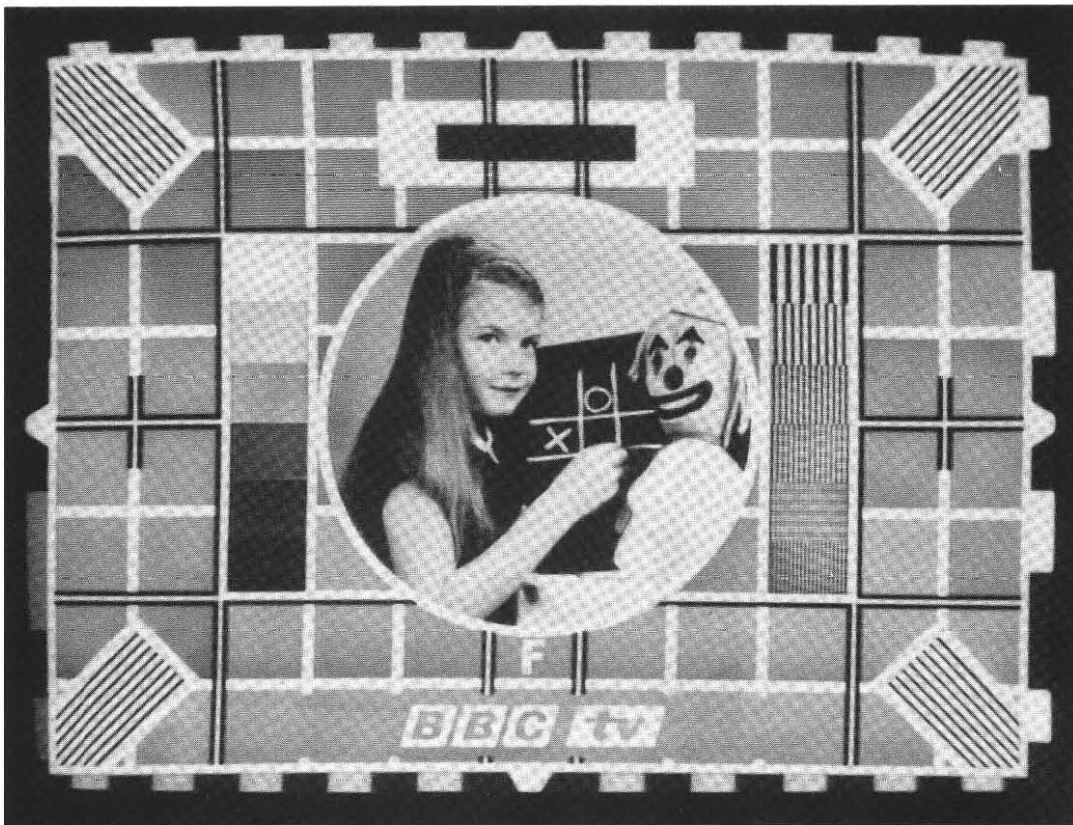


Fig. 9. Amplitude-frequency characteristic of the lowpass filter used in the band splitter in the Extended PAL coder



*Fig. 10. Test Card F – conventional PAL coder and decoder*



*Fig. 11. Test Card F – Extended PAL coder with conventional decoder*



*Fig. 12. Test Card F - Extended PAL coder and decoder*

Fig. 12 shows the green signal from the Extended PAL decoder, with the high-frequency luminance shifted out of band, then shifted back and added back to the low frequency luminance. There is now full luminance resolution with virtually no crosscolour.

Clearly the success of the decoder in joining the high-frequency luminance invisibly back to the low frequency depends on the demodulation phase and the relative delay in the two paths being correct. However, in practice the constraints are not too stringent. A subcarrier phase error of  $18^\circ$  produces a group delay inequality of only 10 ns at 5 MHz; and a static delay inequality of 20 ns between the two signals is virtually invisible, even on a Test Card.

### **3.3. Tests with f.m. modem \***

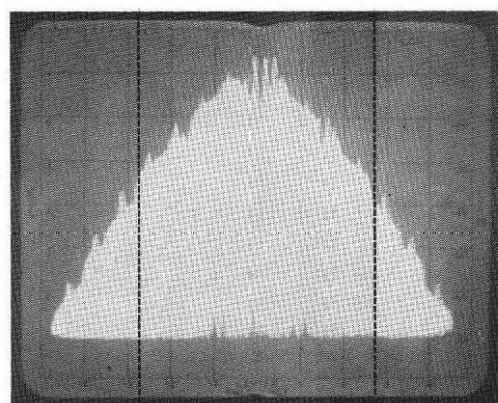
Extended PAL signals have been transmitted through an f.m. modulator and demodulator working at an intermediate frequency of 70 MHz, using an extrapolation of the pre-emphasis curve recommended by the CCIR for PAL signals. Noise could be added to the f.m. signal and the signal bandwidth was limited by a 27 MHz bandpass filter to simulate a satellite channel. A digital sound carrier was added to the baseband video signal.

The spectrum of an f.m. signal extends to infinity, but is always truncated for transmission, giving a small amount of distortion. It is difficult to predict how much of the spectrum of an f.m. video signal can be truncated while still keeping distortions below the level of visibility. The distortion can be reduced, at the expense of an increase in noise, by reducing the deviation. It was expected that because of its wider bandwidth, the Extended PAL signal would suffer more distortion and the deviation would therefore have to be reduced.

The f.m. spectra of a conventional PAL signal and an Extended PAL signal using the same deviation of 13.5 MHz/V are shown in Figs. 13 and 14. The input video signal is a zone plate frequency sweep. The frequency components which lie outside the 27 MHz channel bandwidth are about 20 dB below the level of the undeviated carrier. In practice the effect on the displayed picture of truncating the spectrum of the modulated Extended PAL signal at 27 MHz was negligible, even with a zone plate input signal which would be expected to be a particularly sensitive test for nonlinear distortion. When a digital sound subcarrier at 6 MHz\*\* was added,

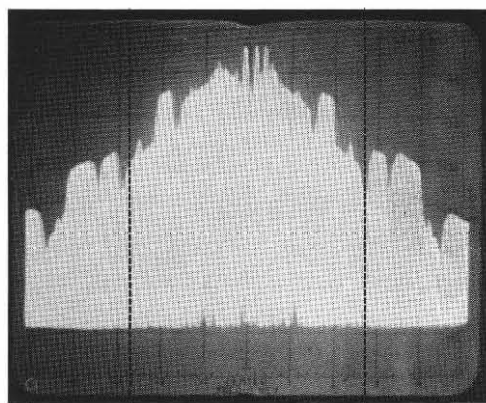
\* These tests were carried out in co-operation with P. Shelswell.

\*\* The use of 6 MHz for the sound carrier was for instrumental convenience; in practice the subcarrier would probably be placed in the region of 6.75 to 7 MHz.



vertical scale 10 dB / div.  
horizontal scale 5 MHz / div.

*Fig. 13. Spectrum of f.m. signal modulated by conventional PAL signal and digital sound signal, before 27 MHz bandpass filter used in tests*

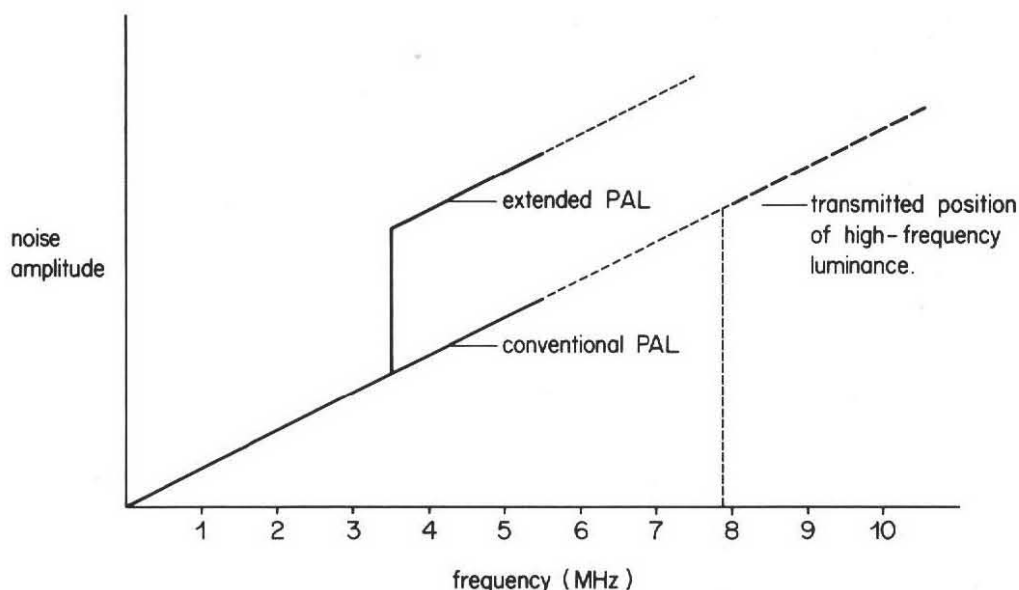


*Fig. 14. Spectrum of f.m. signal modulated by Extended PAL signal and digital sound signal, before 27 MHz bandpass filter used in tests*

some slight distortion was seen on the picture, but no extra distortion was seen which could be attributed to the shifted high-frequency signal. The deviation of the f.m. carrier by the sound subcarrier was 5.6 MHz p-p.

Thus it appears that the deviation of the f.m. carrier need not be reduced if an Extended PAL signal is broadcast. This result is perhaps less surprising when the Extended PAL system is thought of as a redistribution of energy in the baseband signal: the high frequency luminance which is transmitted in the 8–10 MHz region is removed from the 3.5–5.5 MHz region.

The noise spectrum of an f.m. signal (without pre-emphasis) is triangular, rising towards high frequencies. This means that the Extended PAL signal, with its high-frequency luminance transmitted between about 8 MHz and about 10 MHz will be subject to a higher level of noise than will a conventional PAL signal, with the noise spectrum of the displayed luminance signal (without pre-emphasis) being as shown in Fig. 15. The theoretical signal-to-noise ratios can be calculated, given assumptions about signal strength, receiver noise figure etc. One set of assumptions gives luminance s.n.r. at the centre of the service area as 39 dB unweighted or 50.7 dB weighted for conventional



*Fig. 15. Comparison of luminance noise spectra for conventional PAL and Extended PAL after passing through an f.m. channel (no pre-emphasis)*

PAL and 33.4 dB unweighted, 46.6 dB weighted for Extended PAL. However, the difference of 5.6 dB unweighted, 4.1 dB weighted, may be misleading because the noise spectra are different. Noise weighting curves are a compromise, generally intended to deal with noise spectra between flat and triangular, whereas the Extended PAL noise spectrum is hyper-triangular, containing an excess of high-frequency noise, which is less visible. The s.n.r. penalty is subjectively less than the above figures suggest.

Detailed assessments of the noise performance of the Extended PAL system have not yet been carried out; but experience so far has shown that at a carrier/noise ratio of 21 dB, representing the best that is likely to be achieved with a DBS signal, the extra noise with an Extended PAL signal is almost imperceptible, whereas there is a considerable improvement in picture quality due to the increased resolution and freedom from crosscolour. At a carrier/noise ratio of 14 dB, representing the worst that is likely with a DBS signal, the freedom from crosscolour is still worthwhile, but the improvement from adding back the high-frequency luminance, with its associated noise, is debatable.

One way of reducing the noise penalty of the Extended PAL system would be to increase the level of the high-frequency luminance signal before the application of pre-emphasis to the whole signal, giving the high-frequency luminance an extra pre-emphasis of perhaps 3 dB. This should not cause problems since the Extended PAL system caused no visible distortion, even with a zone plate signal, when high-frequency luminance was transmitted without pre-emphasis. Further work is needed to establish the optimum modulation parameters for the Extended PAL system.

#### 4. CONCLUSIONS

An Extended PAL system has been described which virtually eliminates crosscolour and gives improved luminance resolution for high quality receivers while retaining compatibility with conventional PAL decoders. The system uses extra bandwidth available in a satellite or cable transmission channel to transmit the high frequency part of the luminance signal outside the normal video band.

Tests have shown that the wider-bandwidth extended PAL signal can be passed through a 27 MHz f.m. channel as foreseen for direct broadcasting from satellites, without causing noticeable distortions. For an acceptable small penalty in signal-to-noise ratio it gives a worthwhile improvement in picture quality with conventional displays; if high-definition displays become available in the future, the improvement in picture quality will be considerably greater.

#### 5. REFERENCES

1. DREWERY, J.O. 1975. The filtering of luminance and chrominance to avoid cross-colour in a PAL colour system. BBC Research Department Report No. 1975/36.
2. OLIPHANT, A. 1980. Weston clean PAL. BBC Research Department Report No. 1980/1.
3. LENT, S.J. and REED, C.R.G. 1974. Reduction of cross-colour effects in PAL (System I) colour television by the use of low-pass and notch filters. BBC Research Department Report No. 1974/25.

